

Remarks/ Arguments

Upon entry of the foregoing amendments, Claims 1 to 11, 13, 15 to 29, 32 to 35, 37 to 42, 45, 53, and 73 will be pending in this patent application. Claims 1, 8, 13, 28, 37, 38, 42, 45, and 73 have been amended, without prejudice. Claims 12, 14, 43, 44, and 54 to 72 have been canceled in this paper, without prejudice.

Applicants amended paragraph [0038] at page 10 of the instant specification to add the sentence “[i]n certain preferred embodiments of the present invention, the pore-forming phase comprises a C₁ to C₁₃ hydrocarbon compound.” Support for this amendment is found at paragraph [0026] of priority U.S. patent application No. 10/295,568, filed 14 November 2002 (“the 568 application”), of which the instant patent application is a continuation-in-part. The disclosure of the 568 application has been incorporated by reference into the instant patent application. No new matter has been added.

Support for the amendments to Claims 1, 28, 37, 38, and 42, which introduces the recitation of the specific structure-former reagents is found, for example, in original Claim 43.

Support for the amendments to Claims 1, 28, 37, 38, and 42, which introduces the recitation “wherein the at least one pore-forming material is formed from at least one pore-former reagent wherein the pore-former reagent is a gaseous hydrocarbon having from 1 to 13 carbon atoms” is found, for example, in newly-amended paragraph [0038] at page 10 of the present patent application as noted above.

The Action includes rejections under 35 U.S.C. §§ 102(a), 103(a), 112, second paragraph, and provisional rejections under the judicially created doctrine of obviousness-type double patenting. In view of the following remarks, reconsideration and withdrawal of the rejections are requested respectfully.

Discussion of the Rejections Under 35 U.S.C. § 112, Second Paragraph

Claim 72 has been rejected under 35 U.S.C. § 112, second paragraph, as allegedly being indefinite for failing to particularly point out and distinctly claim the subject matter that Applicants regard as their invention. Applicants submit respectfully that the foregoing amendment to Claim 73 renders this rejection moot.

Discussion of the Rejections Under 35 U.S.C. § 103(a)

Claims 1 to 27, 37 to 45, 53 to 66, and 73 have been rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over International Patent Application Publication No. WO 2002/11204 to Grill et al. ("Grill")¹ in view of U.S. Patent No. 6,596,467 to Gallagher et al. ("Gallagher") or EP 1197998 A2 to Zampini et al. ("Zampini"). Claims 28, 29, 32 to 35, and 67 to 72 have also been rejected under 35 U.S.C. § 103(a) as allegedly being unpatentable over Grill in view of Gallagher or Zampini and further in view of U.S. patent application Publication No. 2003/0054115 to Albano et al. ("Albano"). Applicants respectfully traverse this rejection because one of ordinary skill in the art presented with Grill, Gallagher, Zampini, and Albano at the time of the present invention would not have been motivated to combine their teachings in such a way that would produce Applicants' claimed processes.

"A critical step in analyzing the patentability of claims pursuant to section 103(a) is casting the mind back to the time of invention, to consider the thinking of one of ordinary skill in the art, guided only by the prior art references and the then-accepted wisdom in the field." *In re Kotzab*, 55 U.S.P.Q.2d 1313, 1316 (Fed. Cir. 2000). "The invention must be viewed not with the blueprint drawn by the inventor, but in the state of the art that existed at the time." *In re Dembiczak*, 50 U.S.P.Q.2d 1614, 1617 (Fed. Cir. 1999) (quoting *Interconnect Planning*

¹ For the Examiner's convenience, Applicants include herewith as Exhibit A, U.S. Patent 6,312,793, which represents the U.S. equivalent to the Grill reference relied upon in the Action, so the

Corp. v. Feil, 227 U.S.P.Q. 543, 547 (Fed. Cir. 1985). To establish a *prima facie* case of obviousness, "the examiner must show reasons that the skilled artisan, confronted with the same problem as the inventor and with no knowledge of the claimed invention, would select the elements from the cited prior art references for combination in the manner claimed." *In re Rouffet*, 47 U.S.P.Q.2d 1453, 1458 (Fed. Cir. 1998).

Summary of Applicants' Claimed Invention

In one aspect, Applicants' claimed invention defines a process for preparing a porous film, the process comprising the steps of: forming a composite film onto at least a portion of a substrate by a CVD process, wherein the composite film comprises at least one silicon-based structure-forming material and at least one pore-forming material, and wherein the composite film is substantially free of Si-OH bonds; and exposing the composite film to at least one ultraviolet light source within a non-oxidizing atmosphere for a time sufficient to remove at least a portion of the at least one pore-forming material contained therein and provide the porous film, wherein the silicon-based structure-forming material is formed from at least one gaseous linear organosilane or organosiloxane structure-former reagent selected from the group consisting of: diethoxymethylsilane, tetraethoxysilane, dimethyldiethoxysilane, dimethyldimethoxysilane, dimethylethoxysilane, methyldiethoxysilane, triethoxysilane, trimethylphenoxysilane, phenoxysilane, hexamethyldisiloxane, 1,1,2,2-tetramethyldisiloxane, and octamethyltrisiloxane, wherein the at least one pore-forming material is formed from at least one pore-former reagent wherein the pore-former reagent is a gaseous hydrocarbon having from 1 to 13 carbon atoms, and wherein the pore-former reagent is distinct from the at least one linear organosilane or organosiloxane structure-former reagent (*see, e.g.*, amended Claim 1).

In another aspect, Applicants' claimed invention defines a chemical vapor deposition method for producing a porous film represented by the formula $\text{Si}_v\text{O}_w\text{C}_x\text{H}_y\text{F}_z$, where $v+w+x+y+z = 100$ atomic%, v is from 10 to 35 atomic%, w is from 10 to 65 atomic%, x is from 5 to 30 atomic%, y is from 10 to 50 atomic%, and z is from 0 to 15 atomic%, the method comprising: providing a substrate within a vacuum chamber; introducing into the vacuum chamber gaseous reagents including at least one structure-former reagent and a pore-former reagent distinct from the at least one structure-former reagent, wherein the pore-former reagent is a hydrocarbon having from 1 to 13 carbon atoms; applying energy to the gaseous reagents in the vacuum chamber to induce reaction of the reagents to deposit a composite film on the substrate, wherein the composite film comprises at least one structure-forming material and at least one pore-forming material, and wherein the composite film is substantially free of Si-OH bonds; and exposing the composite film to an ultraviolet light source within a non-oxidizing atmosphere for a time sufficient to substantially remove the at least one pore-forming material contained therein to provide the porous film comprising a plurality of pores and a dielectric constant of 2.7 or less, wherein the at least one structure-former reagent comprises at least one linear organosilane or organosiloxane selected from the group consisting of: diethoxymethylsilane, tetraethoxysilane, dimethyldiethoxysilane, dimethyldimethoxysilane, dimethylethoxysilane, methyldiethoxysilane, triethoxysilane, trimethylphenoxysilane, phenoxysilane, hexamethyldisiloxane, 1,1,2,2-tetramethyldisiloxane, and octamethyltrisiloxane (*see, e.g.,* amended Claim 42).

Summary of Grill

Grill teaches a CVD process for making a multiphase material having a low dielectric constant that can be used as an interconnect dielectric layer in IC chips. The process in Grill comprises depositing a multiphase material by reacting a first precursor gas containing atoms of Si, C, O, and H, and at least a second precursor gas containing mainly atoms of C,

H and, optionally, F, N and O. Grill further teaches an optional heating step to post treat the film to allegedly remove at least a part of the volatile organic phase in the multiphase film. Grill teaches that the first precursor is a **cyclic siloxane** that is preferably selected from molecules with ring structures such as 1,3,5,7-tetramethylcyclotetrasiloxane (TMCTS or $C_4H_{16}O_4Si_4$), tetraethylcyclotetrasiloxane ($C_8H_{24}O_4Si_4$), and decamethylcyclopentasiloxane ($C_{10}H_{30}O_5Si_5$) (see Grill at, *e.g.*, page 4, lines 3 to 11).

Differences Between Applicants' Claimed Invention and Grill

There are at least two significant differences between Applicants' claimed invention and Grill. First, because Grill teaches **cyclic** siloxanes, Grill does not teach or suggest Applicants' recited structure-forming precursors, *i.e.*, at least one **linear** organosilane or organosiloxane selected from the group consisting of: tetraethoxysilane, diethoxymethylsilane, dimethyldiethoxysilane, dimethyldimethoxysilane, dimethylethoxysilane, methyl-diethoxysilane, triethoxysilane, trimethylphenoxysilane, phenoxysilane, hexamethyldisiloxane, 1,1,2,2-tetramethyldisiloxane, and octamethyltrisiloxane.

Moreover, Grill does not teach or suggest the recited step of exposing the multiphase film to an ultraviolet light source within a non-oxidizing atmosphere for a time sufficient to substantially remove the at least one pore-forming phase contained therein. Because Grill does not teach or suggest the use of UV to remove the organic phase, the Action combines Grill with Gallagher and/or Zampini, which allegedly teach removal of a porogen from **spin-on** composite films by exposure to heat and/or UV light. In this regard, the Action alleges that Gallagher and Zampini teach that heat and UV light are equivalent methods of removing porogen from a composite film. Applicants disagree respectfully that Grill – either alone or in combination with Gallagher and Zampini – is capable of rendering Applicants' claimed invention obvious for at least the reasons detailed below.

Applicants' Recited **Linear** Structure-Forming Precursors are Not Taught or Suggested by Grill

In the first instance, Applicants' recited linear structure-former reagents are not taught or suggested by Grill and, in fact, exhibit surprising benefits over the cyclic siloxanes disclosed by Grill that were not appreciated by one of ordinary skill in the art at the time of the present invention. Significantly in this regard, the linear structure-former reagents of Applicants' claimed invention have unexpectedly improved mechanical properties relative to, for example, 1,3,5,7-tetramethylcyclotetrasiloxane ("TMCTS"), which is Grill's preferred precursor as is representative of the cyclic siloxanes taught by Grill. Exhibit B attached hereto is a publication entitled "Optimized Materials Properties for Organosilicate Glasses Produced by Plasma-Enhanced Chemical Vapor Deposition" authored by M. O'Neill et al., *i.e.*, the inventors of this patent application ("the O'Neill paper"). In the O'Neill paper, the following organosilicon structure-former reagents were optimized and their mechanical properties were evaluated at comparable dielectric constants: a linear organosilane having an alkoxy substituent (DEMS), an alkylsiloxanes (DMDMOS), a cyclic siloxane (TMCTS) such as that taught by Grill, and a non-alkoxy-containing silane (trimethylsilane). The O'Neill paper reports that "[a]lthough at a given [dielectric constant] there is essentially no change in composition for each sample regardless of precursor, **there are rather large changes in mechanical strength** and structure analysis by FT-IR for films tested" (Exhibit B at page E8.17.2) (emphasis added). Referring to Figure 1 of the O'Neill paper, films made from DEMS and DMDMOS are significantly stronger than films made from Grill's TMCTS or alkylsilanes such as trimethylsilane. Significantly, DEMS and DMDMOS are structure-former reagents within the scope of Applicants' claims as amended above. Thus, the difference in the structure-former reagents between Applicants' claimed invention and Grill is indeed significant in that Applicants' recited structure-former reagents provide surprisingly

mechanically superior films relative to those taught by Grill. If presented with Grill at the time of the present invention, one of ordinary skill in the art would not have expected such superior films and there is no evidence of record that the ordinarily skilled artisan would have expected such differences.² Accordingly, Applicants' claimed invention as amended above is patentable over Grill for at least this reason.

The Combination of Grill with Gallagher and/or Zampini is Improper Because One of Ordinary Skill in the Art Would Not Have Had a Reasonable Expectation of the Success of the Combined Teachings

Because Grill does not teach or suggest the use of UV to remove the organic phase, the Action combines Grill with Gallagher and/or Zampini, which allegedly teach removal of a porogen from **spin-on** composite films by exposure to heat and/or UV light. In this regard, the Action alleges that Gallagher and Zampini teach that heat and UV light are equivalent methods of removing porogen from a composite film. Applicants disagree respectfully with this combination because one of ordinary skill in the art would **not** have been motivated to combine the teachings of Gallagher and Zampini with Grill because one of ordinary skill in the art at the time of the present invention would not have had a reasonable expectation that the resulting combination would have successfully produced Applicants' claimed invention.

The Action incorrectly asserts that "it would have been obvious to one of ordinary skill in the art to employ UV radiation ... for the porogen removal in the process of Grill ... as it

² Moreover, IBM Corporation, the assignee of Grill, has admitted in the public record that linear siloxanes (silicon compounds) are different from cyclic siloxanes. Attached hereto as Exhibit C are excerpts from the prosecution history of U.S. Patent Application 7,049,247 ("the 247 patent"). The claims of the 247 patent define a method for fabricating an ultralow dielectric constant film that includes the step of flowing a first precursor gas having a **linear molecular formula** of $\text{SiRR}'\text{R}''$, where $\text{R}, \text{R}', \text{R}''$, and R''' are the same or different and are selected from H, alkyl, and alkoxy into a chamber of a plasma enhanced chemical vapor deposition (PECVD) reactor. During prosecution, the applicants were faced with a rejection under 35 U.S.C. § 103(a) in view of U.S. Patent No. 6,790,789 ("the 789 patent") to Grill, which discloses cyclicsiloxanes. In response, applicants argued that the 789 patent does **"not teach or suggest** a method in which a first precursor gas comprising **a linear Si compound** is used in conjunction with a second precursor which includes one of an alkene, an alkyne, an ether ... [I]n contrast, Grill et al. disclose a method in which a first **cyclic precursor** ... is used in conjunction with a second cyclic precursor ..." (see Exhibit C at page 33) (emphasis added).

would have been expected to be equivalently useful and effective, since in both cases the dielectric structural material is deposited [and] set before the removal of the porogen such that the porogen's removal would have been expected to be dependent on its composition, not its means of deposition ..." (Action at 6) (emphasis in the original). The Action is mistaken.

One of ordinary skill in the art would not have expected that exposure to UV radiation in the porogen removal process of Grill would have "equivalently useful and effective" (id.) relative to Gallagher and Zampini for at least two reasons. First – and contrary to the Action's assertions – the porogen's removal is not dependent on composition alone, but rather ***is dependent on the means of deposition***. For example, referring to the 1985 book entitled "Plasma Polymerization" by H. Yasuda ("the Yasuda book") (select pages provided as Exhibit D), documents that it is well-known that, not only are there differences between, for example, polymers formed by plasma (referred to herein as "plasma polymers" or "plasma polymerization") and conventional solution polymers such as those taught by Gallagher and Zampini, but that "different materials" (Exhibit D at page 372) result based upon the deposition/polymerization method. The Yasuda book clearly teaches that plasma polymerization is characterized by (1) extensive fragmentation and /or rearrangement of the structural moiety or atoms of the starting material and (2) simultaneously occurring reactions involving many kinds of chemical species; such phenomena are not typical of conventional polymerizations (Exhibit D at pages 4, 5, 166 and 167). According to the Yasuda book, polymers formed by plasma polymerization are, in most cases, highly branched and highly cross-linked as a result of such processes (Exhibit D at 4).

As evidenced by Table 11.1 of the Yasuda book, plasma polymers have higher dielectric constants relative to conventional polymerization of the same monomer. A higher dielectric constant is consistent with the reported increased branching and cross-linking that

results in a plasma polymerization process. Relative to pore formation as recited in Applicants' claimed invention, however, a higher amount of cross-linking makes it inherently ***more difficult*** to produce volatile species upon decomposition by exposure to an energy source such as, for example, ultraviolet radiation. Accordingly, the Action is mistaken in its assertion that the porogen removal process in Gallagher and Zampini "would have been expected to be equivalently useful and effective" in the process of Grill because "the porogen's removal would have been expected to be dependent on its composition, not its means of deposition ..." (Action at 6) (emphasis in the original). Contrary to the Action's assertions, the Yasuda book provides convincing evidence that, at the time of Applicants' invention, there were indeed well-known structural differences for polymer films formed out of the same composition but deposited by a different method.

Next, although Gallagher and Zampini apparently allege that UV radiation would actually remove organic/polymeric porogens, there is absolutely ***no data*** presented by either Gallagher or Zampini to demonstrate that UV radiation would indeed be a successful means to remove porogen. In fact, there is ample reason to doubt Gallagher and Zampini's teaching that UV radiation would actually remove organic/polymeric porogens.

Gallagher teaches porogens that are polymeric:

Substantially compatibilized porogens, typically have a molecular weight in the range of 10,000 to 1,000,000, preferably 20,000 to 500,000, and more preferably 20,000 to 100,000. The polydispersity of these materials is in the range of 1 to 20, preferably 1.001 to 15, and more preferably 1.001 to 10. It is preferred that such substantially compatibilized porogens are cross-linked

(see Gallagher at, *e.g.*, col. 6, lines 50 to 56). Similarly, Zampini teaches polymeric porogens:

The removable porogens may be may be polymers such as polymer particles, or may be monomers or polymers that are co-polymerized with a dielectric monomer to form a block copolymer having a labile (removable) component

(see Zampini at, e.g., page 5, lines 50 to 52).³ It was well known in the art at the time of the present invention that UV radiation actually **stabilized** polymers in a film – **not removed them**. For example, U.S. Patent No. 6,284,050 to Shi et al. ("the 050 patent") (Exhibit E) discloses an ultraviolet-assisted chemical vapor deposition system for improving the adhesion, hardness, and thermal stability of organic polymer films deposited on a semiconductor wafer. The 050 patent, at col. 1, lines 37 to 48, teaches that UV radiation in fact causes organic polymers to cross-link and, therefore, increase their stability:

It is known that **exposing organic polymer films to ultraviolet (UV) radiation promotes cross-linking of polymers in the films, a process which is associated with increased hardness, improved thermal stability, improved film cohesion, and reduced subsequent outgassing of the films**. For example, the improved thermal and mechanical stability obtained by cross-linking fluorocarbon polymer chains is described in R. A. Flinn et al. in "Engineering Materials and Their Applications," pp 370, 409 (2.sup.nd Ed., 1981). It is also known that simultaneous irradiation of organic materials during polymerization is often advantageous for promoting the completion of polymerization

(emphasis added). Thus, Gallagher and Zampini's alleged teaching that polymeric porogens can be removed with UV radiation is doubtful at best. The 050 patent provides evidence that, despite Gallagher and Zampini's unsupported allegations, one of ordinary skill in the art would not have expected UV radiation to remove the polymeric porogens disclosed therein.

Moreover, one of ordinary skill in the art at the time of the present invention and presented with Grill would not have been motivated looked to either of Gallagher or Zampini for guidance with respect to porogen removal. In this regard, Grill co-deposits volatile gaseous hydrocarbon porogens (similar to those recited by Applicants' claimed invention)

³ The Action at page 6 alleges that Zampini discloses hydrocarbon porogens such as norbornene. It does not. To the extent that Zampini teaches the use of norbornene, the norbornene is **reacted** with a monomer such as, for example, TFE (Zampini at page 9, line 46 to page 10, line 20). Norbornene is not employed by itself as a single porogen molecule before it is added to the spin-on composition.

with the cyclosiloxane precursors. As discussed above, Gallagher and Zampini are directed to spin-on materials and, thus, teach removal of a **polymeric** porogen from a material that was deposited as a liquid. Indeed, one of ordinary skill in the art would know (and the Action admits) that spin-on materials are baked (*i.e.*, heated) to set (*see, e.g.*, Zampini at page 15, Example 2). Indeed, if a hydrocarbon having from 1 to 13 carbon atoms (*i.e.*, Applicants' recited pore-forming precursor) could even be deposited in the liquid phase it would be removed during the bake and, thus, would not be present in the film to be removed by exposure to UV. Accordingly, because one of ordinary skill in the art would understand the process differences between CVD and polymeric (*i.e.*, non-volatile) spin-on depositions, one such skilled artisan would not have been motivated to look to the spin-on art for teachings with respect to porogen removal. Thus, for at least these reasons, Applicants' claimed invention is patentable over Grill and the combination of Grill with Gallagher and/or Zampini. Accordingly, reconsideration and withdrawal of the rejections under 35 U.S.C. § 103(a) are requested respectfully.

Discussion of the Obviousness-Type Double Patenting Rejections

Claims 1 to 8, 10 to 15, 22, 25 to 28, 32 to 34, 37, 41 to 45, and 53 to 73 have been rejected under the judicially-created doctrine of obviousness-type double patenting as allegedly being unpatentable over claims 1 to 3, 7 to 14, 16 to 22 and 25 to 41 of commonly-owned U.S. Patent No. 7,098,149 (previously co-pending Application No. 10/379,466), optionally in view of U.S. Patent No. 6,068,884 to Rose et al. ("Rose"). Although Applicants traverse this rejection, Applicants submit herewith a Terminal Disclaimer in compliance with 37 C.F.R. § 1.321 to overcome the rejection.

Claims 1 to 29, 32, 35, 37 to 45, and 53 to 73 have been provisionally rejected under the judicially-created doctrine of obviousness-type double patenting as allegedly being

unpatentable over claims 55 to 93 of commonly-owned copending Application No. 10/295,568 ("the 568 application"), optionally in view of Rose. Although Applicants disagree that the claims of the above-identified applications render the present claims obvious, Applicants request that the provisional obviousness-type double patenting rejections be held in abeyance until the patentability of claims under 35 U.S.C. § 103(a) is resolved. Upon some identification of allowable subject matter, a suitable terminal disclaimer may be filed if the 568 application issues before the allowance of the claims of the present application.

Claims 1 to 13, 15, 16, 25 to 29, 32 to 35, 37 to 45, and 53 to 73 have been provisionally rejected under the judicially-created doctrine of obviousness-type double patenting as allegedly being unpatentable over claims 1 to 14, 20 to 22, 24 to 27, and 30 of commonly-owned copending Application No. 10/842,503 ("the 503 application"), optionally in view of Rose. Although Applicants disagree that the claims of the above-identified applications render the present claims obvious, Applicants request that the provisional obviousness-type double patenting rejections be held in abeyance until the patentability of claims under 35 U.S.C. § 103(a) is resolved. Upon some identification of allowable subject matter, a suitable terminal disclaimer may be filed if the 503 application issues before the allowance of the claims of the present application.

Claims 1 to 29, 32, 35, 37 to 45, and 53 to 73 or Claims 1 to 13, 15, 16, 25 to 29, 32 to 35, 37 to 45, and 53 to 73 have been provisionally rejected under the judicially-created doctrine of obviousness-type double patenting as allegedly being unpatentable over claims 1 to 47 and 50 to 54 of commonly-owned copending Application No. 11/228,223 ("the 223 application"), optionally in view of Rose. Although Applicants disagree that the claims of the above-identified applications render the present claims obvious, Applicants request that the provisional obviousness-type double patenting rejections be held in abeyance until the patentability of claims under 35 U.S.C. § 103(a) is resolved. Upon some identification of

allowable subject matter, a suitable terminal disclaimer may be filed if the 223 application issues before the allowance of the claims of the present application.

Conclusion

Applicants believe that the foregoing constitutes a complete and full response to the Action of record. Applicants respectfully submit that this application is now in condition for allowance. Accordingly, an indication of allowability and an early Notice of Allowance are respectfully requested.

The Commissioner is hereby authorized to charge the fee required and any additional fees that may be needed to Deposit Account No. 01-0493 in the name of Air Products and Chemicals, Inc.

Respectfully submitted,

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